Prins Maurits Laboratorium TNO

TNO-Defensieonderzoek

Lange Kleiweg 137
Postbus 45
2280 AA Rijswijk

Fax 015 - 84 39 91
Telefoon 015 - 84 28 42

(1)

TNO-rapport

PML 1992-15

Instrumented experiments aboard the frigate "WOLF". Wolf II: Background information concerning the transducers and mounting methods used

August 1992

Copy no: - 5

Author (s):

R.M. van de Kasteele
Th.L.A. Verhagen

Total Number of Pages :
(ex. distr. list and RDP)

29

Number of Annexes :

-

Number of Figures :

13

Number of Tables :

14

DO assignment no.:

A88/KM/419

Number of Copies :

26

Classification

Report :

UNCLASSIFIED

Title:

UNCLASSIFIED

Summary:

UNCLASSIFIED

Annex(es) :

-

Nederlandse organisatie voor toegepast-natuurwetenschappelijk onderzoek

TNO-Defensieonderzoek bestaat uit

Summary

Within the framework of the research into the vulnerability of ships, an experimental investigation took place in 1989 aboard the frigate "WOLF" of the "Roofdierklasse" (PCE 1604 class) (Wolf, Phase II).

In this report, background information is given with respect to the transducers used and the mounting and protection methods applied during the instrumented experiments in the crew front and aft sleeping compartments. Moreover, attention is paid to the registration equipment and the signal analysis system used.

Samenvatting

In het kader van het onderzoek naar de kwetsbaarheid van schepen zijn in 1989 een aantal experimenten uitgevoerd op het fregat "WOLF" van de Roofdierklasse (PCE 1604 class) (Wolf, Fase II).

In dit rapport wordt aanvullende achtergrond informatie gegeven betreffende de gebruikte opnemers en de wijze van monteren en beschermen tijdens de geïnstrumenteerde experimenten in het manschappen slaapcompartiment zowel op het voor- als op het achterschip. Daarnaast wordt aandacht besteed aan de gebruikte registratie apparatuur en het signaalbewerkingssysteem.

CONTENTS

	SUMMARY/SAMENVATTING	2
	CONTENTS	3
1	INTRODUCTION	5
2	BLAST MEASUREMENTS	7
2.1	Pressure transducers	7
2.2	Mounting method of the pressure transducers	8
3	QUASI-STATIC PRESSURE MEASUREMENT	11
3.1	Quasi-static pressure transducers used	11
3.2	Mounting method	12
4	STRAIN MEASUREMENT	14
4.1	Strain gauges used	14
4.2	Mounting method strain gauges	15
5	ACCELEROMETERS	16
5.1	Accelerometers used	16
5.2	Mounting method accelerometers	17
6	BREAKWIRE MEASUREMENT	18
7	TEMPERATURE MEASUREMENT	19
8	THE RECORDING CABLES	21
9	THE REGISTRATION EQUIPMENT	22
10	SIGNAL PROCESSING	24

11	CONCLUSION	24
12	AUTHENTICATION	25
13	REFERENCES	26
13.1	General references	26
13.2	FRET reports	27
13.3	WOLF, phase I reports	27
13.4	WOLF, phase II reports	28
13.5	Roofdier Blast damage reports	29

1 INTRODUCTION

In order to obtain quantitative as well as qualitative information on the effects of internal and external explosions on a frigate, a number of (instrumented) experiments were performed on the frigates "FRET" and "WOLF" (Figure 1). These are Roofdier class frigates, the former United States Navy PCE 1604 class, which were decommissioned by the Royal Netherlands Navy. A general overview of the Roofdier trials is given in Table 1.

Table 1 A general overview of the Roofdier trials

Fret I	June/September 1987	(v.d. Kasteele and Verhagen, 1989)
Wolf I	October/ November 1988	(v.d. Kasteele and Zwaneveld, 1989)
Wolf II	September/October 1989	(Verhagen and v.d. Kasteele, 1992)

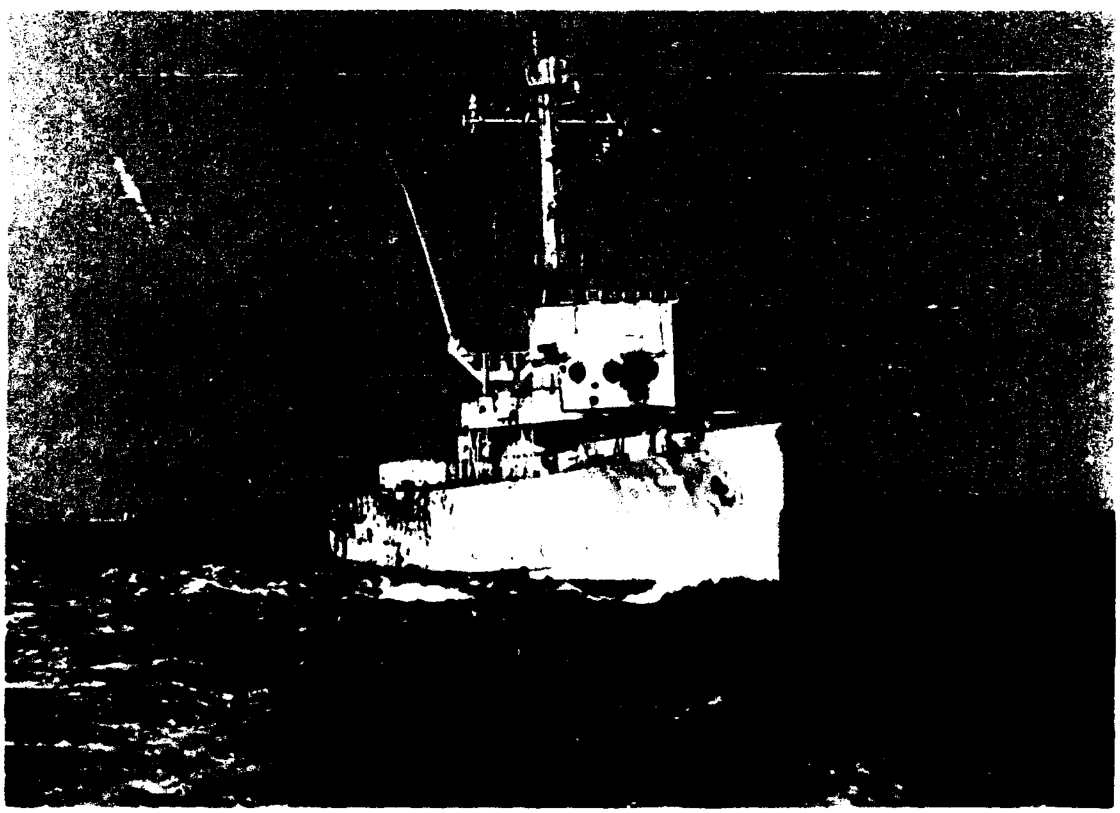

Figure 1 Wolf frigate (891052-6)

Pressure, strain, acceleration etc. were recorded during the Wolf Phase II bare charge experiments. These experiments were performed in the crew aft as well as the crew forward sleeping compartment. In the crew aft sleeping compartment, the 2, 5.5 and 15 kg TNT bare charge experiments were performed. The volume of this compartment was ±77 m^3, thus realizing a "charge density" of ±0.026, ±0.072 and ±0.20 kg/m^3.
The 3 and 12 kg TNT bare charge experiments were performed in the crew forward sleeping compartment. The volume of this compartment was ±105 m^3, thus resulting in a "charge density" of ±0.029 and ±0.11 kg/m^3.
During these Phase II experiments, special attention was paid to the blast resistance of the watertight doors (i.e. the 2, 3 and 5.5 kg TNT experiments), the resistance of the structure (the 12 kg TNT experiment) and the rupture of structural elements (the 15 kg TNT experiment).

The recordings of the instrumented Wolf Phase II experiments presented conform to the previous reports dealing with the recordings of the Fret and Wolf Phase I experiments. Each report can be regarded as an independent report. It goes without saying that it is not within the scope of these reports to discuss the recordings in detail or even to compare the recordings with theoretical predictions. That will be an integral part of the reports presented by van Erkel (1992).

Due to the increased knowledge and experience gained from the Fret and Wolf Phase I trials, modified mounting and protection techniques were used during the Wolf Phase II trial. It is for this reason that this report treats the general background information as well as the applied mounting and protection methods. For the sake of completeness, a description is also given of the registration equipment and the signal analysis system used.

2 BLAST MEASUREMENTS

2.1 Pressure transducers

Piezo-electric blast sensors (PCB, type 112A, 113A and 113A03) were used to measure the blast. Deformation of the membrane with a quartz crystal connected to it generates an electrical charge which can be converted with a charge amplifier (Vibro, type TA3C and PCB, type 462A) to a voltage. Finally, the voltage can be recorded with the registration equipment. The technical specifications of the pressure transducers are summarized in Table 2 and the specifications of the charge amplifiers used are specified in Table 3.

Table 2 Technical specification of the pressure transducers

Manufacturer	PCB	PCB	PCB
Type	112A	113A	113A03
Range	20MPa	20 MPa	100 MPa
Resonant Frequency	250 kHz	500 kHz	500 kHz
Linearity	<1%	<1%	<1%
Rise Time	2 μs	1 μs	1 μs

Table 3 Technical specification of the charge amplifiers

Manufacturer	Vibro	PCB
Type	TA3C	462A
Range	10-1.1 10^6 pC	0.1-1.1 10^6 pC
Max. Frequency	150 kHz (-3 dB)	100 kHz (± 5%)
Output	20 V P.P.	20 V P.P.
Linearity	<0.05%	<0.1%

In the reports dealing with the recordings, the abbreviations B1-B8 were used. Table 4 shows the relation between the abbreviations used, the pressure transducers and amplifiers applied.

Table 4 Relation between abbreviations used, pressure transducers and amplifier applied

	Transducer	Amplifier		Transducer	Amplifier
B1	PCB 112A	TA3C	B5	PCB 113A	TA3C
B2	PCB 112A	TA3C	B6	PCB 113A	PCB462A
B3	PCB 113A03	TA3C	B7	PCB 113A03	PCB462A
B4	PCB113A03	TA3C	B8	PCB 113A03	PCB462A

2.2 Mounting method of the pressure transducers

Special attention was paid to the mounting of the pressure transducers. A series of experiments was performed to optimize the construction in which the blast sensors were mounted. This special construction consisted of four main parts:

- a metal disc (diameter 200 mm, thickness 15 mm) on which a tube (diameter 30 mm) with an external screw thread (size M60x3) was centrally welded;
- a cylindrical metal ring (diameter 200 mm, thickness 50 mm) with an internal screw thread (size: M60x3);
- a rubber seal (diameter 30 mm, length 30 mm);
- a metal stop (diameter 29.9 mm, length 43 mm).

The components used for mounting and a piezo-electric pressure transducer are shown in Figure 2.

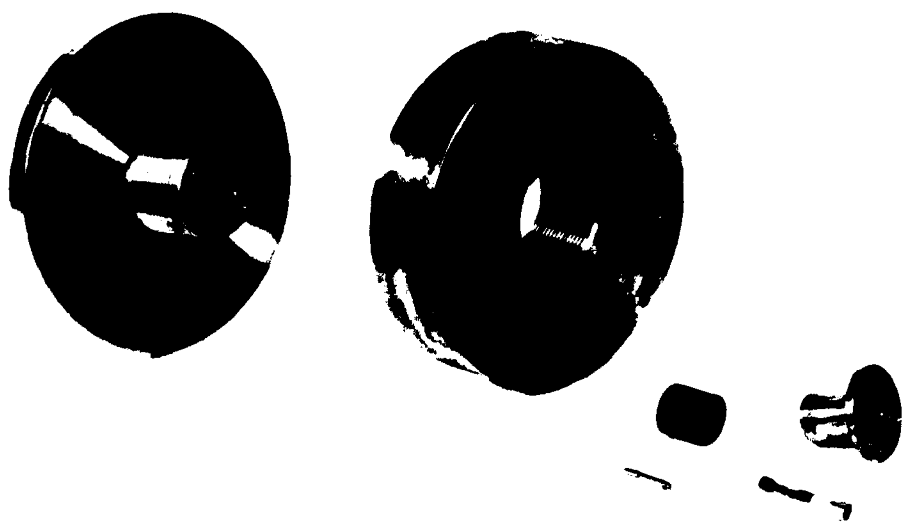

Figure 2 The piezo-electric pressure transducer and the mounting device components (910311)

This construction was used in two different ways, i.e. built in and built on the wall. The method used depended on the local structure of the wall.

- Built in the wall: the disc was placed in the explosion compartment, while the tube of the disc was put through a specially made hole in the wall. The ring was welded on both sides of the wall.
- Built on the wall: the disc with metal ring were welded together on the wall.

During the experiments in the crew aft sleeping compartment, transducers B1 and B2 were mounted on the wall (i.e. the hull), while B3, B4, B5, B6, B7 and B8 were mounted in the wall. However, due to the local structure in the crew forward sleeping compartment all transducers were mounted on the wall.

The pressure transducer was placed in the centre of the disc, sealed with the rubber seal and the metal stop. To increase the stiffness at the measurement location, four profiles were used, welded on the disc and on the wall.
In Figure 3 the "built in" situation is shown, whereas in Figure 4 the "built on" situation is shown. Thermal compound (Wakefield, type 120-8) was used to suppress the temperature influences and to diminish the influence of flash of the explosion.

Figure 3 The "built in" pressure transducer with mounting device (890961-6)

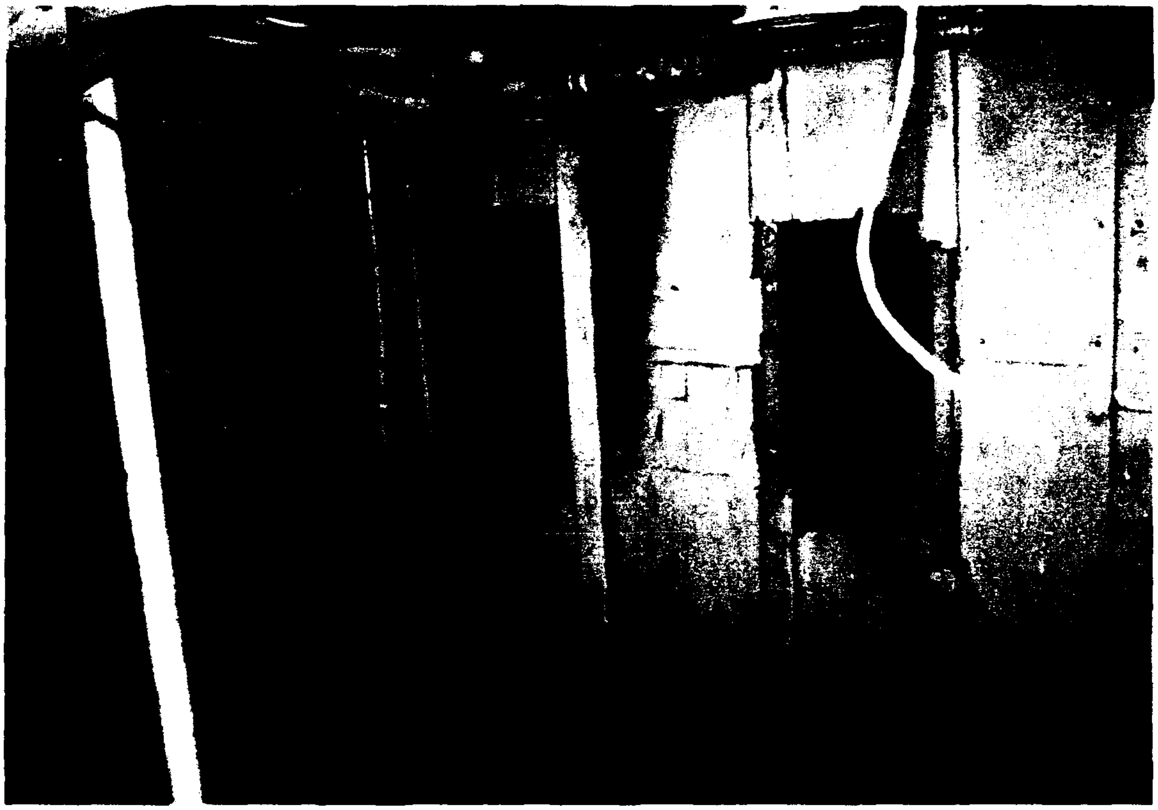

Figure 4 The "built on" pressure transducer with mounting device (891056-2)

3 QUASI-STATIC PRESSURE MEASUREMENT

3.1 Quasi-static pressure transducers used

The quasi-static pressure was registered with piezo-resistive pressure transducers (Druck, type PDCR200) in combination with a bridge amplifier (SE Laboratories, type 994). The principle of this kind of transducer is very simple. A resistance wire is placed on the membrane of the transducer. Deformation of the membrane results in a variation of the wire's resistance. In combination with a Wheatstone bridge circuit, this resistance variation results in a voltage variation. The latter can be registered conventionally. In contrast with the piezo-electrical transducers, no leakage of charge (drift) is possible. Therefore these kind of transducers are suitable for "long time" measurements. The technical details of the piezo-resistive pressure transducers and the bridge amplifiers used are summarized in Tables 5 and 6.

Table 5 Technical specifications of the piezo-resistive pressure transducers

Manufacturer	Druck
Type	PDCR200
Range	3.5, 6, and 60 bar
Resonance Frequency	180 kHz
Linearity	0.2%
Bridge Voltage	10 V
Sensitivity	150 mV nominal

Table 6 Technical specifications of the bridge amplifier

Manufacturer	SE Laboratories
Type	994
Max. Frequency	50 kHz (-3dB)
Voltage	20 V P.P.
Bridge Voltage	7-15 V

3.2 Mounting method

The transducer, placed in a synthetic (Makrolon) adapter, was sealed with felt (thickness 2 mm) in a cylinder of steel (diameter 90 mm, height 50 mm). The components used are shown in Figure 5. The steel cylinder is mounted on a steel plate, separated by two rubber vibration dampers. The steel plate was welded on the measurement position. The rubber dampers and the felt were used to prevent transducer resonance. Thermal compound (Wakefield, type 120-8) was used to diminish the thermal influences on the membrane response. Figure 6 shows a mounted quasi-static pressure transducer in the frigate.

Figure 5 A quasi-static pressure transducer with the mounting device components (881338-9)

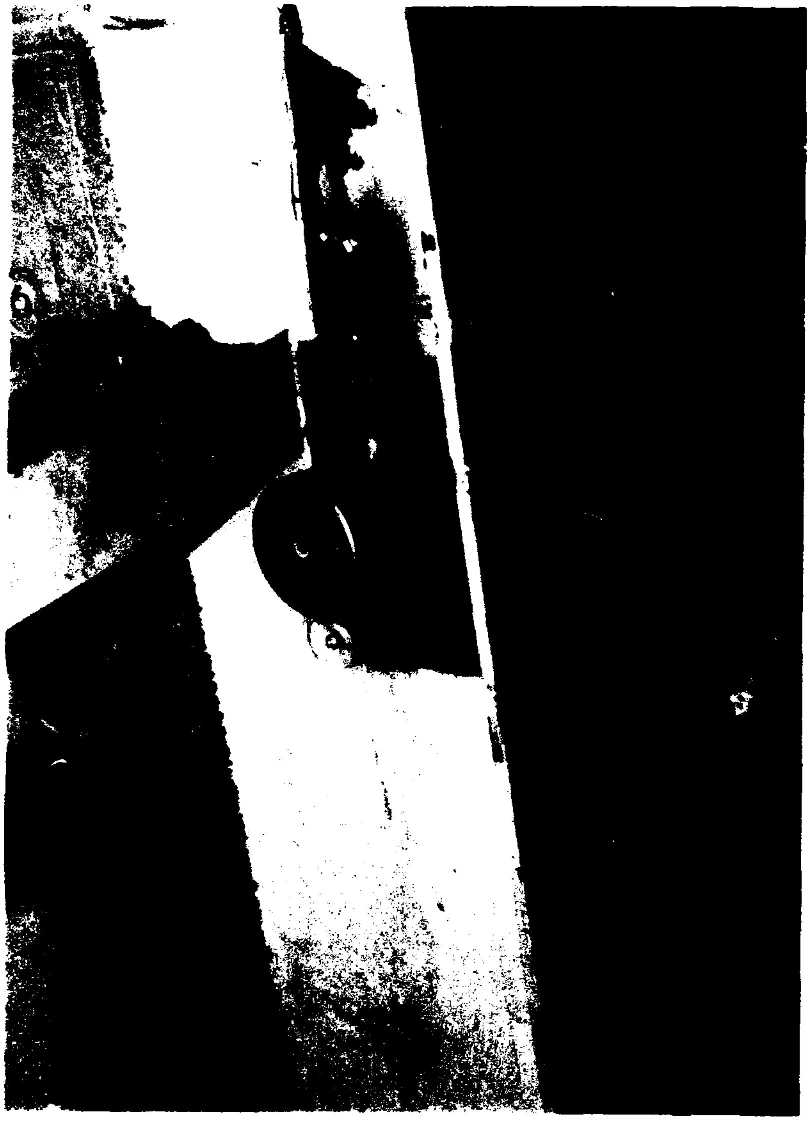

Figure 6 Mounted quasi-static pressure transducer (891057-32)

4 STRAIN MEASUREMENT

4.1 Strain gauges used

The deformation of walls and stiffeners was recorded with strain gauges. A strain gauge consists of a synthetic carrier with a copper/nickel wire as the sensing element. Deformation of the strain gauge causes a change of resistance in the sensing element, which is converted into a change of voltage by means of a Wheatstone bridge circuit. During the experiments, strain gauges (made by Tokyo Sokki) were used with a maximum gain of 2% and 10%, as shown in Figure 7. The specifications of the strain gauges are summarized in Table 7. The strain gauge amplifier, developed within the Prins Maurits Laboratory - TNO, is in fact a combination of the Wheatstone bridge circuit and a differential amplifier, the technical specifications of which are summarized in Table 8.

Table 7 Specification of the strain gauges

Manufacturer	Tokyo Sokki	Tokyo Sokki
Type	YL10	PL10
Length	10 mm	10 mm
Strain Limit	10%	2%
Carrier	cellulose	polyester
Sensing Element	copper/nickel	copper/nickel
Resistance	120 ± 0.3 Ohm	120 ± 0.3 Ohm
K-factor	1.99	2.07

Table 8 Specification of the bridge amplifier

Max. Frequency	30 kHz (-3 dB)
Max. Output	20 V P.P.
Gain	10, 100, 200, 1000x
Principle	bridge of Wheatstone

4.2 Mounting method strain gauges

The surface preparation consisted of paint removal and abrasion followed by degreasing with different solvents. The strain gauges were glued onto the prepared measurement locations with the aid of a cyanoacrylate based adhesive from Tokyo Sokki. This adhesive is guaranteed against lengthening up to 20%. The mounted gauges were finally protected against mechanical violence and fire by a Hottinger-Baldwin coating. To protect the strain gauge against possible EMP phenomena during the explosion, the aluminium foil on the coating was attached to the wall with a (parker) screw. This is shown in Figure 7.

Figure 7 A glued strain gauge (891057-8)

5 ACCELEROMETERS

5.1 Accelerometers used

The acceleration measurements were performed with the aid of three different types of transducers; the Entran EGC-240-D, the Endevco 2262-1000 and the Hottinger B12-2000. The Entran EGC-240-D and the Endevco 2262-1000 are damped piezo-resistive accelerometers, while the Hottinger B12-2000 accelerometer is constructed according the induction principle. Both the Entran and the Endevco were connected to an SE Labs type 994 bridge amplifier, whereas the Hottinger was connected to a Hottinger carrier wave amplifier, type KWS/T. The technical specifications of the accelerometers are summarized in Table 9. The specifications of the bridge amplifier and the carrier wave amplifier are summarized in Table 10.

Table 9 Specifications of the accelerometers

Manufacturer	Entran	Endevco	Hottinger
Type	EGC-240-500D	2262-1000	B12-2000
Range	500 g	1000 g	250 g
Resonance Frequency	3500 Hz	6000 Hz	2000 Hz
Linearity	±1%	±1%	±1%
Excitation	15 V	10 V	---
Carrier Wave Freq.	---	---	5000 Hz
Sensitivity	0.4 mV/g	0.5 mV/g	---
Damping	0.7 cr at 80 F	± 0.7	0.6 at 20 °C
Principle	Piezo-resistive	Piezo-resistive	Induction

Table 10 Specifications of the amplifiers

Manufacturer	SE Laboratories	Hottinger
Type	994	KWS/T
Max. Frequency	50 kHz (-3dB)	1300 Hz
Max. Output	20 V P.P.	4 V P.P.
Bridge Voltage	7-15 V	---
Carrier Wave Freq.	---	5000 Hz

In the reports dealing with the recordings, the abbreviations A1-A13 were used. In Table 11 the relation between the abbreviations used and these accelerometers are summarized. The amplifiers used are also given in this table.

Table 11 Relation between abbreviations used, and accelerometer and amplifier used

	Accelerometer	Amplifier
A1, A11, A13	Hottinger	Hottinger
A2, A3, A4, A8, A12	Endevco	SeLabs
A5, A6, A7, A9	Entran	SeLabs

5.2 Mounting method accelerometers

The transducers were mounted on a block of steel (dimension 45x30x25 mm) with two M3 screws, using oil to improve the signal transmittance. The blocks of steel were welded (to a stiffener) at the marked locations as shown in Figure 8.

Figure 8 Mounted accelerometer on a block of steel (890961-30)

6 BREAKWIRE MEASUREMENT

Breakwires were used to determine the possible moment of collapse of the watertight doors. The (plumb) breakwires used had a diameter of 0.5 mm and were tight mounted with a synthetic adapter behind the door. The breakwire was connected to a micro-switch which was part of a current circuit. Breaking of the wire resulted in a change of signal. A impression of this set-up is given in Figure 9.

Figure 9 Breakwire set-up (891057-15)

7 TEMPERATURE MEASUREMENT

The temperature measurement in the explosion compartment was performed with a chromel-alumel thermo couple. The thermo couple was coupled to an amplifier with chromel-alumel wires. An Ectron amplifier was used. This type of amplifier has a zero point compensation and a 200 Hz low pass filter. The technical specifications are summarized in Tables 12 and 13.

Table 12 Specifications of the thermo couples

- Thermo couple 0.5 mm Inconel 600
- Chromel/Alumel with grounded function
- Time constant ± 0.8 s,
(time necessary for registration of 63.2%
of temperature increase)

Table 13 Specifications of the amplifier

Manufacturer	Ectron
Type	400
Frequency Range	dc - 300 Hz
	(low pass filtered up to 200 Hz)
Linearity	0.05%
Output	20 V P.P.
Gain	20 - 1000x

To prevent the thermo couple from malfunctioning due to the shock wave or mechanical violence during the experiment, the thermo couple was glued in a tube of steel. The steel tube was directly mounted onto a cable connector, secured with plastic binders. An impression is given in Figure 10.

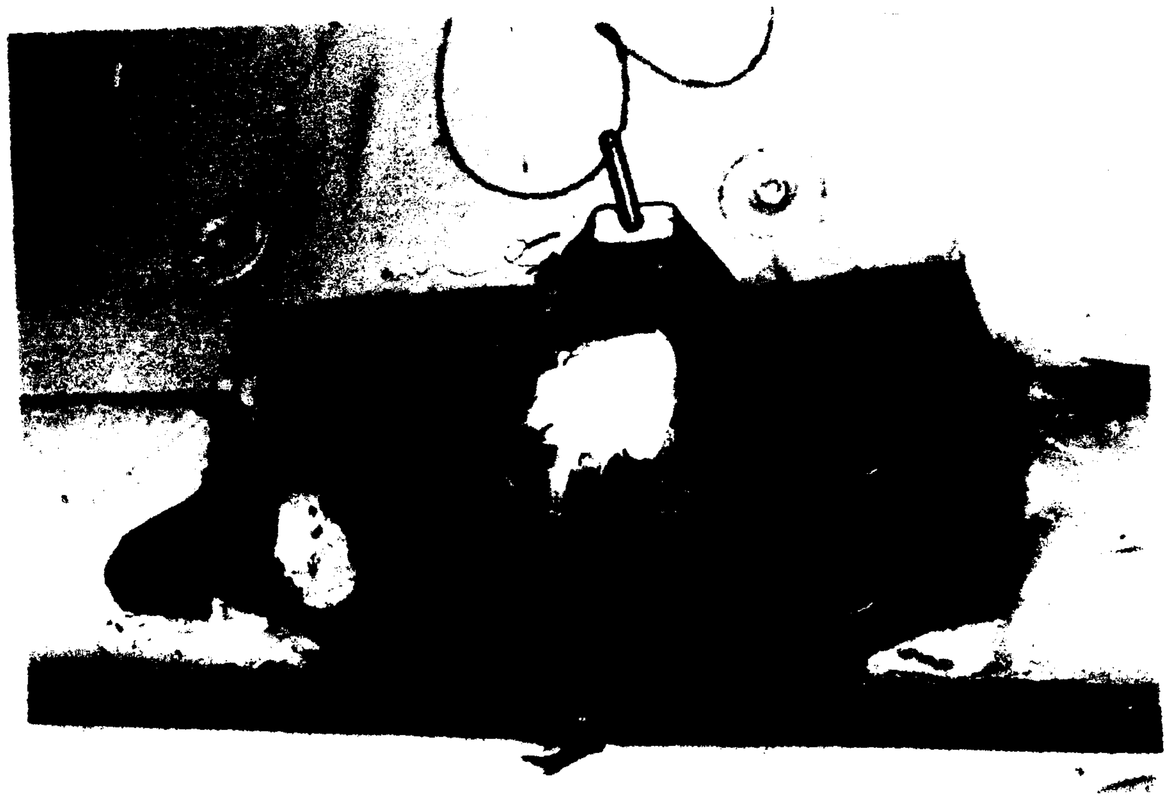

Figure 10 A thermo couple mounted on a QSD transducer (891057-13)

8 THE RECORDING CABLES

During the previous experiments (Fret and Wolf Phase I), a number of signals were only recorded up to a short time after the explosion due to the malfunction of the recording cables. Recording cables in the explosion compartment were often torn from the transducers due to the shock wave and the mechanical violence of the experiment. The connection of the transducer to the recording cable appeared to be a weak point. To improve the registration of the signals during the Wolf phase II experiments, the length of the recording cables in the experimental compartment was minimized. Behind each transducer a steel ring was welded to which a steel wire was fixed. The steel wire was tightly fixed between the walls of the adjacent compartment guiding the recording cables to a safer place. An impression of the steel wires in a compartment adjacent to the experimental compartment is given in Figure 11.

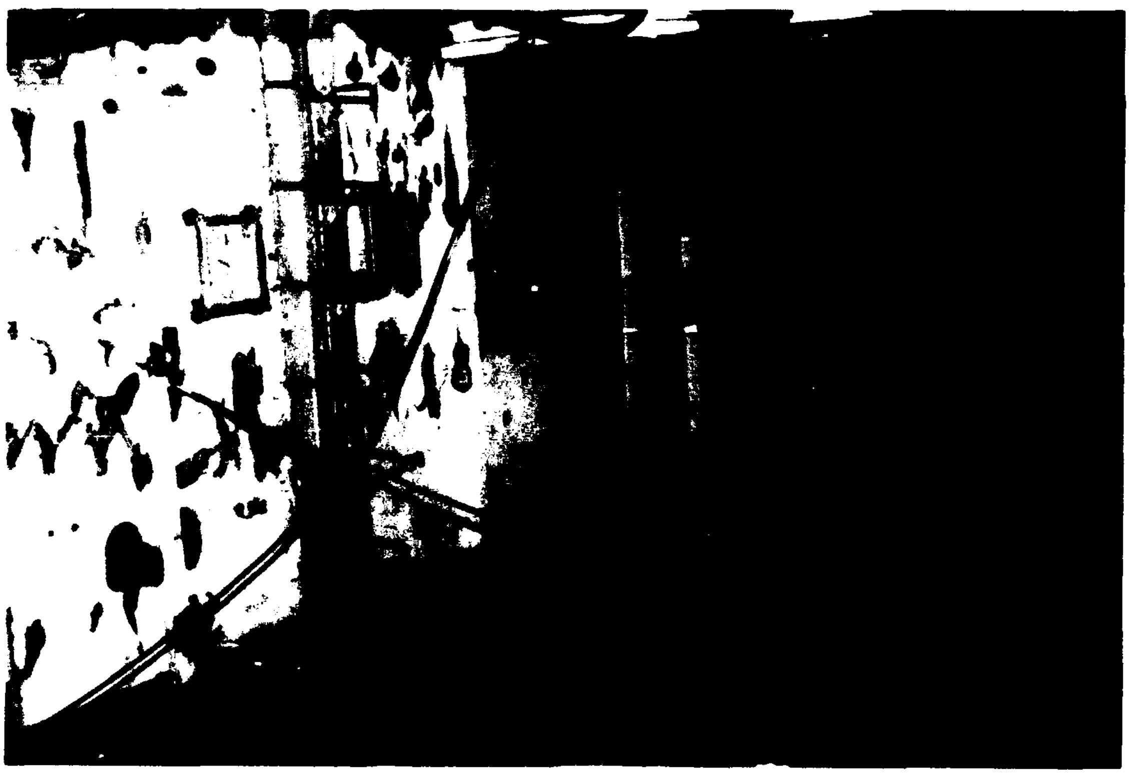

Figure 11 Steel wires guiding the recording cables through an adjacent compartment (890961-22)

The small connector cables between the blast transducers and the coaxial recording cable were replaced by more robust cables and connectors which were placed in the adapter of the blast transducer.

9 THE REGISTRATION EQUIPMENT

To record the signals, a fourteen and a twenty-one channel tape-recorder were used. The specifications of these recorders are summarized in Table 14.

Table 14 Specifications of the tape recorders

Manufacturer	SE Laboratories	
Type	7000A and 7000D	
No. of Channels	14	21
Max. Frequency	80 kHz, WBI, 120 ips, FM modulation	
Input	20 V P.P.	
Output	3 V P.P.	
Linearity	±0.5%	
Signal Freq. Response	±0.5 dB	

The tape-recorders were started by a control unit which was triggered by a radiographic signal. This control unit also checks the performance of the registration equipment. A schematic view of the registration set-up is shown in Figure 12.

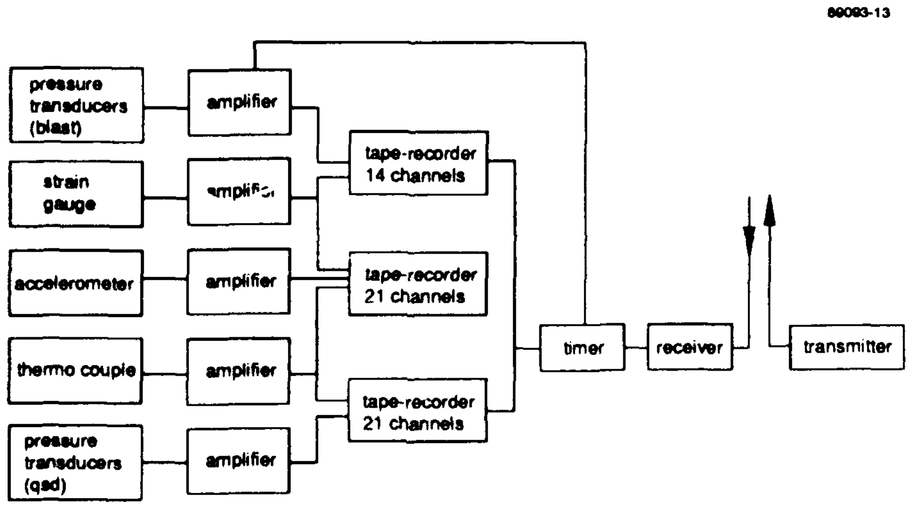

Figure 12 Schematic view of registration set-up

All measuring and controlling equipment aboard the frigate was installed on tables, spring mounted suspended in a specially prepared container which was placed on the main deck. An impression of the contents of this container are shown in Figure 13.

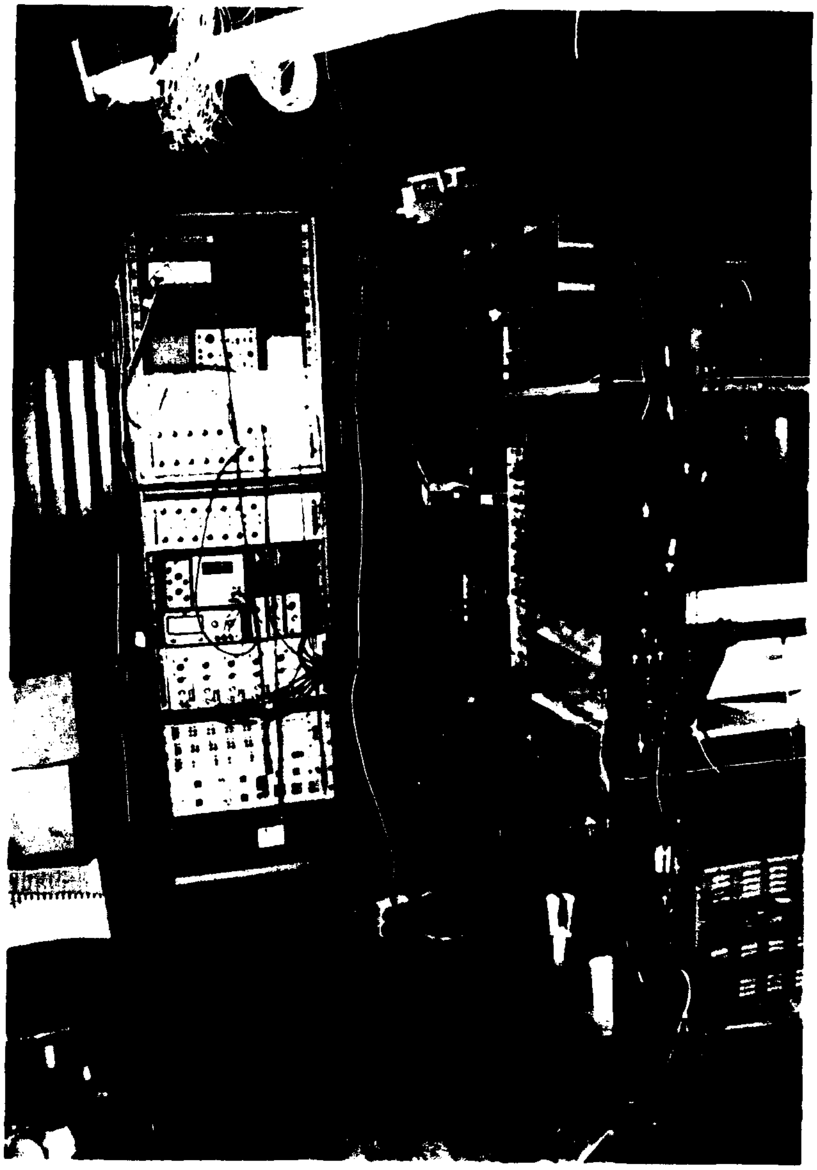

Figure 13 Measurement set-up during the Wolf Phase II experiments (891057-19)

10 SIGNAL PROCESSING

The analogue recorded signals were digitized at our laboratory with a Transiscope (manufacturered by Difa Benelux, type TS9000). This is a 14-channel, 12-bit A/D converter with memory capacity and the possibility to show the digitized signals on a screen. The sample time is adjustable from 2 µs up to 10 s, which means a dynamic range up to 250 kHz. Each channel can register up to 64 K samples. The Transiscope is linked to a personal computer via an IEEE-interface. The personal computer is used to control the Transiscope as well as to communicate with the Prins Maurits Laboratory's central computer system where the final digital signal processing takes place. The central computer system consists of a number of VAX computers of which the µVAX 3300 is used for signal processing. The software developed for the digital signal processing was developed and described by Jasper (1985) and Verhagen (1987, 1989).

11 CONCLUSION

During the Wolf Phase II trial a number of instrumented experiments in the crew forward sleeping compartment as well as in the crew aft sleeping compartment were performed.
To get a deeper understanding and thus a better interpretation of the recorded signals as presented in the Wolf II reports, it is necessary to know which transducers were used during the experiments, the way they were mounted as well as the way they were protected against fire, mechanical violence etc..
Increased experience in these phenomena from the previous Fret and Wolf phase I trials has resulted in a number of modifications and improvements in the applied mounting and protection methods. This justifies this report which incorporates the additional information concerning the transducers and amplifiers used during the Wolf Phase II experiments. In addition, attention was paid to the recording cables, the registration equipment and the signal processing system.

From the recordings reported in the set of Wolf phase II reports, it can be concluded that the mounting methods used and the way the transducers were protected increased the reliability of the registered signals.

12 AUTHENTICATION

The realization of the Wolf phase II trial as presented in this set of reports was achieved due to the effort of a number of people from the Explosion Prevention Group: the technicians, Mr. M.W.L. Dirkse, Mr. Ph. van Dongen, Mr. R.M. van de Kasteele and Mr. A.M. Steenweg, who carried out the experiments and processed the recordings.
We would also like to acknowledge the supporting services of the Royal Netherlands Navy.

Date:

1 april 1992

J. Weerheijm
(Project Manager)

Th.L.A. Verhagen
(Author)

R.M. van de Kasteele
(Author)

13 REFERENCES

13.1 General references

Jasper, J.C.M.
Inleiding tot een systeem voor digitale signaalverwerking
PML - TNO, Rapport No. 1985-IN-92 (in Dutch)

Verhagen, Th.L.A.
PMLSIGnal/scp,
programma's voor interactieve digitale signaalbewerking
PML - TNO, Rapport No. 1987-IN-14 (in Dutch)

Verhagen, Th.L.A.
Een overzicht van de mogelijkheden van het interactieve digitale signaalbewerkingspakket PMLSIGNAL
PML - TNO, Rapport No. 1989-IN-25 (in Dutch)

Verhagen, Th.L.A.
Methoden voor de interpretatie van meetsignalen, gebaseerd op het een-massaveer systeem
PML - TNO, Rapport No. 1989-IN-26 (in Dutch)

Verhagen, Th.L.A.
Het interactieve digitale signaalbewerkingspakket PMLSIGNAL
Een beknopt overzicht van de mogelijkheden
PML - TNO, Rapport No. 1991-IN-47 (in Dutch)

Verhagen, Th.L.A.
Het interactieve digitale signaalbewerkingspakket PMLSIGNAL
Een algemeen overzicht van de mogelijkheden
PML - TNO, Rapport No. 1992-IN-1 (in Dutch)

13.2 FRET reports

Kasteele, R.M. van de; Verhagen, Th.L.A.
Geïnstrumenteerde beproeving van het roofdierfregat "FRET"
Meetresultaten van de proef in het manschappen slaapverblijf op het voorschip
PML - TNO, Rapport No. 1989-32 (in Dutch)

Kasteele, R.M. van de; Verhagen, Th.L.A.
Geïnstrumenteerde beproeving van het roofdierfregat "FRET"
Meetresultaten van de proef in het manschappen slaapverblijf op het achterschip
PML - TNO, Rapport No. 1989-33 (in Dutch)

Kasteele, R.M. van de; Verhagen, Th.L.A.
Geïnstrumenteerde beproeving van het roofdierfregat "FRET"
Achtergrond informatie met betrekking tot gebruikte opnemers en bevestigingsmethoden
PML - TNO, Rapport No. 1989-34 (in Dutch)

13.3 WOLF, phase I reports

Kasteele, R.M. van de; Zwaneveld, J.H.C.
Geïnstrumenteerde beproeving aan boord van fregat "WOLF"
Wolf I: Meetresultaten van de proeven in kabelgat/ankerlierruimte en onderofficiers verblijf/kombuis
PML - TNO, Rapport No. 1989-45 (in Dutch)

Kasteele, R.M. van de; Zwaneveld, J.H.C.
Geïnstrumenteerde beproeving aan boord van fregat "WOLF"
Wolf I: Resultaten van de metingen verricht in de stuurhut en de wasplaats
PML - TNO, Rapport No. 1990-12 (in Dutch)

Kasteele, R.M. van de
Geïnstrumenteerde beproeving aan boord van fregat "WOLF"
Wolf I: Achtergrond informatie met betrekking tot gebruikte opnemers en bevestigingsmethoden
PML - TNO, Rapport No. 1989-36 (in Dutch)

Zwaneveld, J.H.C.
Overpressure, blast, strain and accelerations in a ship compartment due to near external explosions
PML - TNO, Report No. 1989-18

13.4 WOLF, phase II reports

Verhagen, Th.L.A.; Kasteele, R.M. van de
Instrumented experiments aboard the frigate "WOLF"
Wolf II: Measurement results of the 2 kg TNT experiment in the crew aft sleeping compartment
PML - TNO, 1992-10

Verhagen, Th.L.A.; Kasteele, R.M. van de
Instrumented experiments aboard the frigate "WOLF"
Wolf II: Measurement results of the 3 kg TNT experiment in the crew front sleeping compartment
PML - TNO, 1992-11

Verhagen, Th.L.A.; Kasteele, R.M. van de
Instrumented experiments aboard the frigate "WOLF"
Wolf II: Measurement results of the 5.5 kg TNT experiment in the crew aft sleeping compartment
PML - TNO, 1992-12

Verhagen, Th.L.A.; Kasteele, R.M. van de
Instrumented experiments aboard the frigate "WOLF"
Wolf II: Measurement results of the 12 kg TNT experiment in the crew front sleeping compartment
PML - TNO, 1992-13

Verhagen, Th.L.A.; Kasteele, R.M. van de
Instrumented experiments aboard the frigate "WOLF"
Wolf II: Measurement results of the 15 kg TNT experiment in the crew aft sleeping compartment
PML - TNO, 1992-14

Kasteele, R.M. van de; Verhagen, Th.L.A.
Instrumented experiments aboard the frigate "WOLF"
Wolf II: Background information concerning the transducers and mounting methods used
PML - TNO, 1992-15

13.5 Roofdier Blast damage reports

Erkel, A.G. van
Blast tests on ship doors
PML-TNO, 1990-31

Erkel, A.G. van
Roofdier internal blast damage
Part I: Bare charge experiments in the aft sleeping compartment
PML-TNO, 1992-(to be published)

Erkel, A.G. van
Roofdier internal blast damage
Part II: Bare charge experiments in the front sleeping compartment
PML-TNO, 1992-(to be published)

Erkel, A.G. van
Roofdier internal blast damage
Part III: Experiments with shells and asymetrical located bare charges
PML-TNO, 1992-(to be published)

Erkel, A.G. van
Roofdier internal blast damage
Part IV: lessons learned
PML-TNO, 1992-(to be published)

REPORT DOCUMENTATION PAGE

(MOD NL)

1. DEFENSE REPORT NUMBER (MOD-NL)	2. RECIPIENT'S ACCESSION NUMBER	3. PERFORMING ORGANIZATION REPORT NUMBER
TD91-2529		PML1992-15
4. PROJECT/TASK/WORKUNIT NO.	**5. CONTRACT NUMBER**	**6. REPORT DATE**
292489093	A88/KM/419	August 1992
7. NUMBER OF PAGES	**8. NUMBER OF REFERENCES**	**9. TYPE OF REPORT AND DATES COVERED**
29	22	Final

10. TITLE AND SUBTITLE

Instrumented experiments aboard the frigate "WOLF". Wolf II: Background information concerning the transducers and mounting methods used.
(Geïnstrumenteerde beproevingen aan boord van het fregat "WOLF". Wolf II: Achtergrond informatie betreffende de gebruikte opnemers en de wijze van monteren.)

11. AUTHOR(S)

Th.L.A. Verhagen,
R.M. van de Kasteele

12. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

TNO Prins Maurits Laboratory
P.O. Box 45, 2280 AA Rijswijk, The Netherlands

13. SPONSORING AGENCY NAME(S) AND ADDRESS(ES)

DMKM
P.O. Box 20702, 2500 ES The Hague

14. SUPPLEMENTARY NOTES

15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTE))

Within the framework of the research into the vulnerability of ships, an experimental investigation took place in 1989 aboard the frigate "WOLF" of the "Roofdierklasse" (PCE 1604 class) (Wolf, Phase II).

In this report background information is given with respect to the transducers used and the mounting and protection methods applied during the instrumented experiments in the crew front and aft sleeping compartments.

Moreover attention is paid to the registration equipment and the signal analysis system used.

16. DESCRIPTORS	IDENTIFIERS
Frigates	Pressure Measurement
Vulnerability	Strain Measurement
Experimental Investigation	Accelerometers
TNT	Temperature Measurement
Explosion Effects	Pressure Sensors
Blast Measurement	Tape-recorders
Signal Processing	

17A. SECURITY CLASSIFICATION (OF REPORT)	17B. SECURITY CLASSIFICATION (OF PAGE)	17C. SECURITY CLASSIFICATION (OF ABSTRACT)
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED

18. DISTRIBUTION AVAILABILITY STATEMENT	17D. SECURITY CLASSIFICATION (OF TITLES)
Unlimited Distribution	UNCLASSIFIED

DISTRIBUTION LIST

1	DWOO
2	HWO-KL
3	HWO-KLu
4	HWO-KM
5/7	TDCK
8/11	Ministerie van Defensie DMKM, Afd. Scheepsbouw
12	Hoofddirecteur DO-TNO
13	Lid Instituuts Advies Raad PML Prof. drs. P.J. van den Berg
14	Lid Instituuts Advies Raad PML Prof. Ir. M.A.W. Scheffelaar
15	Lid Instituuts Advies Raad PML Prof. Ir. H. Wittenberg
16	PML-TNO, Directeur Programma; daarna reserve
17/21	PML-TNO, Secretariaat Divisie 2, Groep Explosiepreventie en -bescherming
22/24	PML-TNO, Secretariaat Divisie 3, Groep Wapeneffectiviteit
25	PML-TNO, Documentatie
26	PML-TNO, Archief